Comparison of the Compressive Strength of Concrete made With Limestone Screenings And with Torpedo Sand

F. B. Whitney

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Comparison of the Compressive Strength of CONCRETE
made with
LIMESTONE SCREENINGS
and with
TORPEDO SAND.

A THESIS

presented by

Fred B. Whitney.

TO THE

PRESIDENT and FACULTY

of

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE

of

BATCHELOR OF SCIENCE IN CIVIL ENGINEERING

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Having completed the prescribed course of study in Civil Engineering

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Most of the railroads of Chicago are now engaged in elevating their tracks. Of course retaining walls are needed to keep the tracks of the companies within their respective rights of way, and these walls have been made of different materials. They were first built of rubble masonry and the abutments at right angles to the tracks, being placed on each side of street subways, of ashlar. The work on such walls was neceasarily slow and expensive, as they had to be in perfect alignment and of course skilled masons were employed to build them.

Concrete walls on the other hand are much cheaper than those built of stone, because of the class of laborers and kind of material required. After the forms are erected, any common laborer can tamp concrete, although some skillful person to mix it properly is needed. The first concrete abutments built in Chicago were put up in 1898 by the Brownell Improvement Company under the direction of Mr. Henry Lee. They were placed under the tracks of the Chicago, Rock-Island and Pacific Railway, just south of the Pennsylvania Lines crossing at 63rd Street, Englewood. Soon afterward the masonry work in connection with the elevation and depression of the tracks that cross each other at 16th Street, was made of concrete. This fact is thought to have given an impetus to the use of concrete in Chicago, not only on railroads but to all kinds of structural engineering where masonry was required. It is a fact that from that time on, very little, if any stone has been used for masonry walls in elevating the tracks of the railroads centering at Chicago.

Concrete for retaining walls has been made of the following ingredients: (Refers to vicinity of Chicago.)

CEMENT, SAND, CRUSHED LIMESTONE.

CEMENT, LIMESTONE SCREENINGS, CRUSHED LIMESTONE.

Screenings obtained from crushed stone in a stone crushing plant, have up to a few years ago been considered a waste product. Even now a great many engineers will not allow their use to be inserted in specifications for making concrete, neither will they use them under any circumstances. Among other engineers it has been a mooted question whether concrete made with screenings or with sand is the ~~best~~ better, both as to wearing qualities and to strength.

The Pennsylvania Company have used limestone screenings in concrete for retaining walls and abutments on its track elevation work in Chicago, for the past two years. While employed as masonry inspector for the said railroad during the summer of 1904, I had a good opportunity to study concrete made in that way. Because of the variance of opinion which I heard expressed while working, and to prove to my own satisfaction which materials to be obtained in the vicinity of Chicago are the best for making concrete, the following tests are the result:

MATERIALS.

The materials which I used in making my tests were very kindly furnished me by Mr. W. J. Black, Superintendent of the Brownell Improvement Company, Chicago, and were the following:

CEMENT, SAND, LIMESTONE SCREENINGS, CRUSHED LIMESTONE, CEMENT.

Peerless Portland Cement manufactured by the Peerless Portland Cement Company, Union City, Michigan was used. The tests of Portland Cement made during the year 1904 furnished to me by Mr. A. Lundteigen, Chemist for the Company are as follows:

Total number of briquettes tested	9713
Average of all 7 day tests, neat cement	862 lbs.
" " " 28 " " " "	952 "
" " " 3 mo. " " "	1048 "
" fineness on 100 mesh sieve	95.6%

Boiling test invariably good.

The tests for tensile strength which I made were as follows:

	I day.			7 days.			28 days.		
	% of water			% of water			% of water		
	23%	24%	25%	23%	24%	25%	23%	24%	25%
	I73	86	86	422	440	632	930	8I0	720
	I42	82	I33	460	468	7I0	795	730	790
	I45	I4I	I60	494	466	655	740	8I0	
		I78	I30	500	452	562	870	820	
					397			890	
								770	
								750	
	I67								
Av.	I67	I59	I4I	485	454	640	834	798	755

Average I day I56 lbs. Average 7 days 526 lbs. Average 28 days 796 lbs.

I used three different quantities of water in order to get a fair average and did not count those results which were manifestly wrong.

The specifications for tensile strength for briquettes one inch square in section as adopted by the American Society for Testing Material~~s~~,is as follows:

AGE.	Strength Limits.
24 hours in moist air ------------------------------------	I50 - 550 Lbs.
7 days (I day in moist air, 6 days in water)-----------	450 - 550 lbs.
28 " (I day " " " 27 " " "	550 - 650 "

I tested the cement for fineness and found the fineness on a I00 mesh sieve to be 95%. For testing the briquettes I used Fairbanks Automatic Cement Testing Machine. This machine is similar to a pair of scales and consists of a lever arm which rests on knife edges. A small tank is built at the top of the vertical support which contains

very fine shot. The briquette to be tested is held by clamps placed at the middle of the vertical support. On one end of the lever arm a bucket is hung and power is applied by allowing the shot to run into the bucket. When the briquette breaks, the upper clamp goes up and automatically shuts off the flow of shot. In order to find the number of pounds required to break the speciman, the bucket is removed from the spout end of the machine and attached to the other end of the lever arm. A counter poise weight is added in its place and the shot weighed. This weight is the result sought.

For pictures of this machine see Plate I.

SAND.

Torpedo Sand from Hammond, Indiana was used which contained a very small amount of loam. All the sand passed through a No. 4 sieve (4 meshes per lineal inch) then through a No. 20 sieve (20 meshes per lineal inch) and 96% was caught on a No. 30 sieve (30 meshes per lineal inch)

SCREENINGS.

Limestone screenings are the waste product from a crusher plant. The screenings that I used were from the Brownell Improvement Companies' Crusher Plant at Thornton, Illinois, and ranged in size from one quarter inch down to dust. It may be stated here that the Brownell Improvement Company has a special kind of Crushing Machinery to grind the larger sized screenings into powder, when concrete with a nicely finished surface is required. Such screenings are called "double F."

KEY TO PLATE I.

FAIRBANKS' AUTOMATIC CEMENT TESTING MACHINE.

N - N Clamps to hold speciman.

P - Screw to tighten clamps.

F - Bucket into which shot runs.

D - Beam on which scale is placed.

B - Tank containing shot.

K - K "Stop" to limit movement of beam.

I - Automatic cut off to stop flow of shot.

E - Balance ball.

M - Spout through which shot passes.

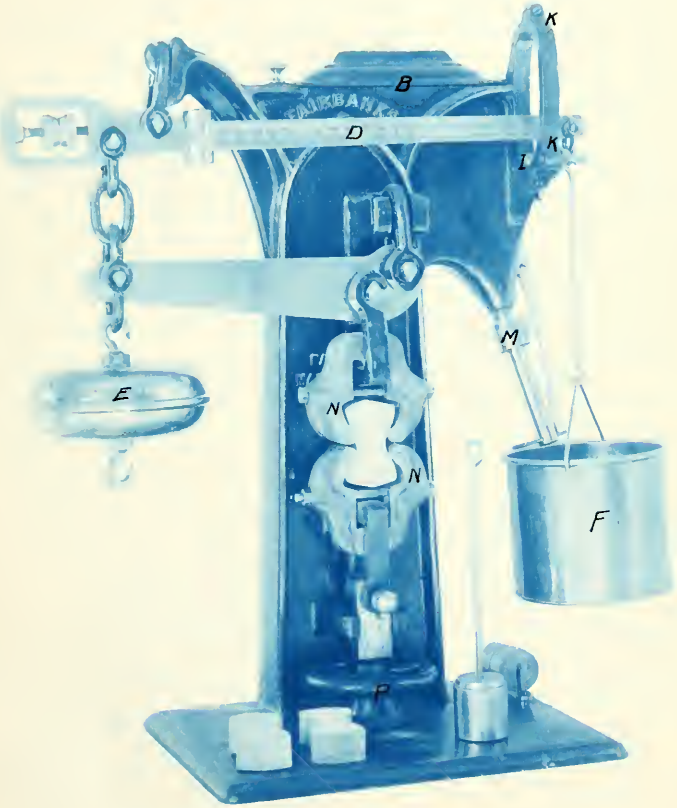


PLATE 1.

PLATE 2.

SHOWING CEMENT LABORATORY IN WHICH CONCRETE WAS MADE.

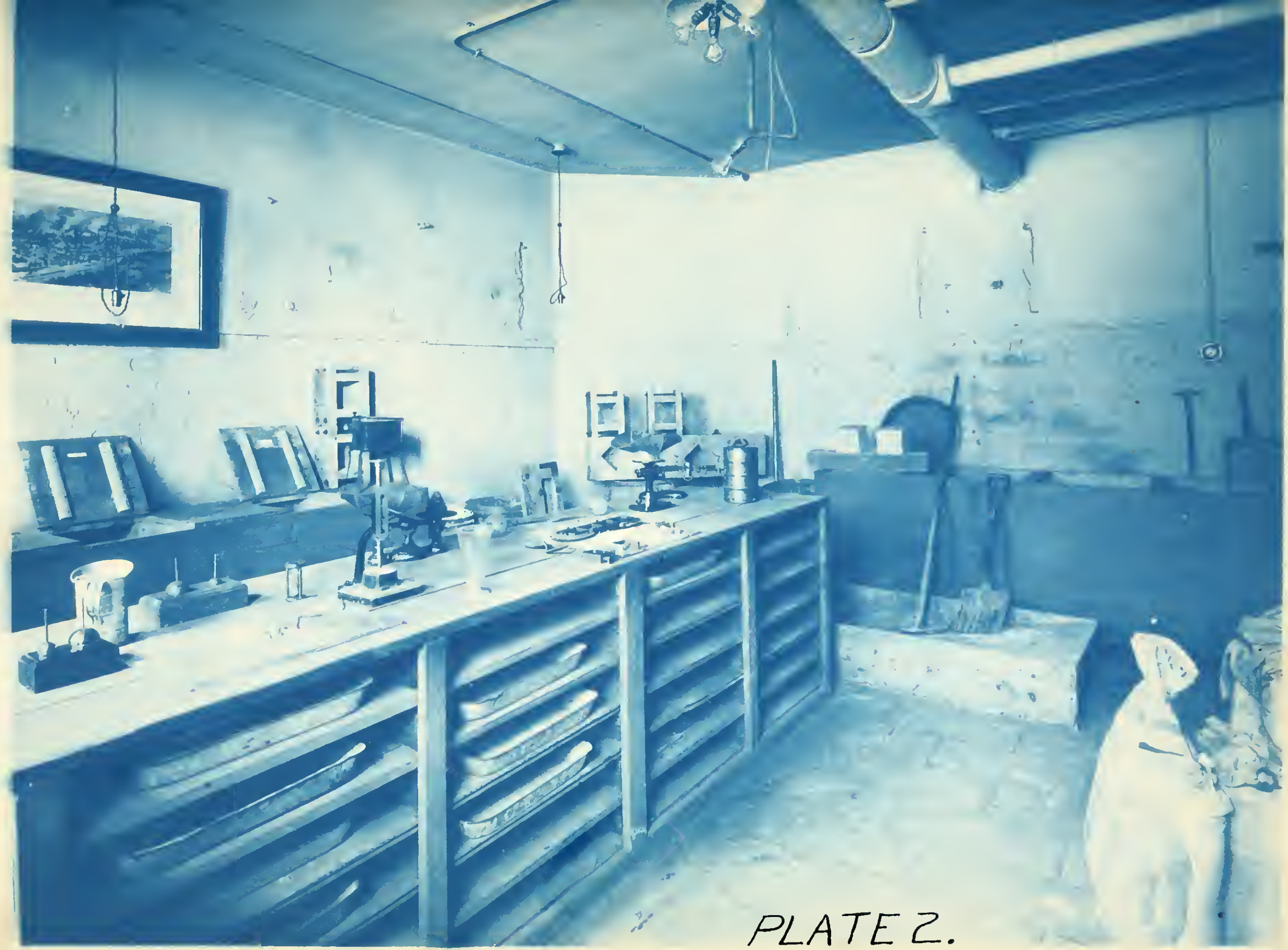


PLATE 2.

STONE.

Crushed limestone which was used in making my tests, was also a product of the Crusher at Thornton. It ranged in size from one inch down to one quarter inch. Such stone is called "Crusher Run."

APPARATUS.

(A) Apparatus for making concrete.
(B) Apparatus for testing concrete.

(A) Mixing Box.

MIXING BOX- 4 '6" long, 2 '7" wide and 7" high. Made of I" lumber. See Plate 3, Fig. I.

SPADE.

Spade which was used was II½" long and 9 3/4" wide.

HOE.

Hoe used in mixing concrete was 8" along the edge.

TAMPING ROD.

Tamper used for ramming the comcrete into the moulds was a round steel bar, I9 I/2" long and I I/4 " in diameter. It weighed 7 pounds.

MOLDS.

Two kinds of molds were used in forming the concrete cubes. One was a gang mold containing four molds, 4 '3 I/2" long, I2" wide and 7" deep, and was made in two pieces, the two halves being fastened together with I" bolts. A bottom board extended underneath all. See Plate 3, Fig. 3.

The other molds were single and collapsible, I3" long and

KEY TO PLATE 3.

FIG. I- Mixing Box.

FIG. 2- Tamping Rod.

FIG. 3- Gang Mold.

FIG. 4- Individual Mold.

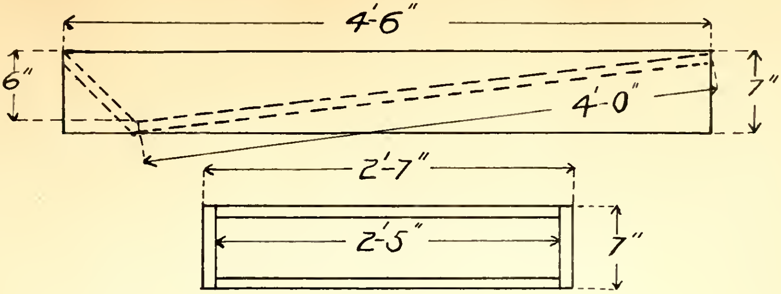


Fig. 1.

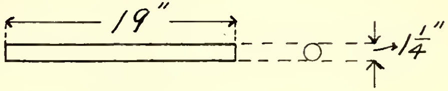


Fig. 2.

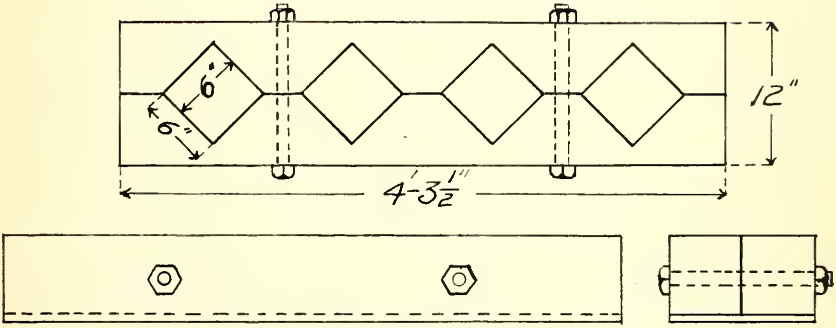


Fig. 3.

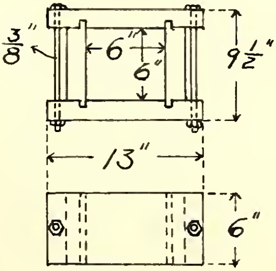


Fig. 4.

PLATE 3.

9 I/2" wide; the two sides being connected with I/2" bolts. The inside dimensions of all molds was 6" x 6" x 6" See Plate 3, Fig. 4.

(B) Apparatus for testing concrete.

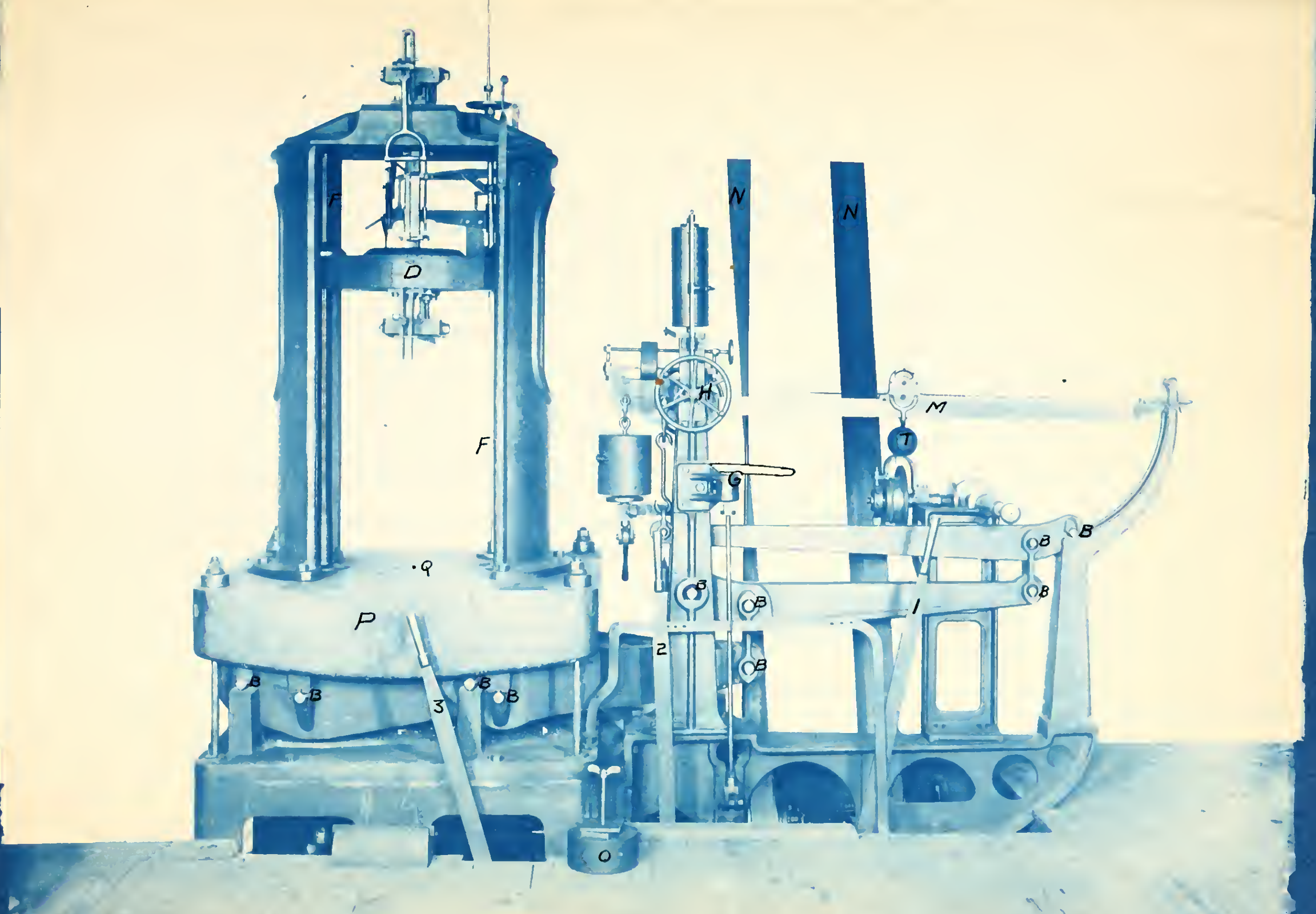
For testing the concrete cubes after standing the specified amount of time, the Riehle' 200,000 lb. capacity machine was used. The machine is shown in Plate 4. The principal upon which it works is described below. Power is supplied by a motor which is communicated to the machine by the belts "NN". The apparatus upon the machine in the figure is not that which I used, but is of the form used to make tensile tests. For compressive tests it is necessary to fasten the compression block "O" to the platform "D" and to insert a similar compression block in the platform "P" at the point "Q". Lever I and Gear "G" control the application of power to the machine. The lever allows a faster speed to be derived than does the gear. Lever 2 controls the speed of Platform "D" and Lever 3 controls the motion (i.e. up and down) of the same platform. From what has been stated it is plain that the operation of the machine is dependant on the movement of platform "D" This platform bears down upon the speciman placed upon the compression block at "Q", and ita applied weight is communicated by a system of levers through the knife edges "B" to the scale arm "M" which must be balanced before applying power. To keep the beam in equilibrium, the counter weight "T" is run out on the scale arm by means of the wheel "H". After the elastic limit and ultimate strength has been reached, the arm drops, and the weight at which the speciman crushed can be read.

KEY TO PLATE 4.

Riehlé 200,000 lb. Capacity Testing Machine.

N - N	Belts transmitting power to machine.
O	Compression block.
D	Movable platform.
P	Stationary platform.
Q	Point at which compression block is attached.
G	Gear controlling power.
I	Lever " "
2	" " speed.
3	" " motion.
B - B	Knife edges.
M	Scale arm.
T	Counter weight.
H	Wheel which controls position of "T".
F - F	Screws upon which platform "D" moves.

PLATE 4.



PROPORTIONS.

The size of the cubes which were used had a great deal of weight in proportioning the mixture of my concrete, as I wished to get as dense a mixture as possible. After determining the voids in the several materials, I decided upon a I: 2: 4: mixture; that is one part of cement, two parts of sand or screenings as the case might be, and four parts of crushed stone. The method I used to determine the voids in the sand, screenings and stone was this: First, put material in a vessel, then poured water into the vessel until the voids of the material were entirely filled and water rose to the surface; Second, determined amount of this water; Third, determined amount of water necessary to fill the vessel; Fourth, divided the first amount of water by the second, and Fifth, multiplied this result by I00 to obtain the percentage of voids in the material.

Weight of stone alone in pail ------------------20 lbs.
" " " voids filled with water --------26 "
" " " equivalent am't of water -------I4.5"

$\frac{6}{I4.5} = .4I$ $.4I \times I00 = 4I\% = \%$ of voids in stone.

I000 cu. cm. of sand taken.
280 " " " water "

$\frac{280}{I000} = .28$ $.28 \times I00 = 28\% = \%$ of voids in sand.

I000 cu. cm. of screenings taken.
270 " " " water "

$\frac{270}{I000} = .27$ $.27 \times I00 = 27\% = \%$ of voids in screenings/

From several determinations made, I found that the voids in both screenings and sand varied from 25% to 30%

6" X 6" X 6" = 216 no. of cu. inches in one mold. It is necessary to put this much stone into each mold and to fill the voids with mortar. As I mixed enough concrete to fill three molds at each mixing, the following calculations are figured on that basis.

216 cu. in. X 3 = 648 cu. in.
41 % = % of voids in stone.
41 X 648 = 265.68 cu. in.
Add 40%
40 X 265.68 = 106.272 cu. in.
265.68 + 106.272 = 371.952 cu. in.
27% = average % of voids in sand and screenings
.27 X 371.95 = 110.4265 cu. in.
Add 20%
110.4265 X .20 = 22.0853 cu. in.
110.4265 + 22.085 = 132.5118 cu. in.

231 cu. in. in one gallon.
Therefore 58 cu. in. in one quart.

$\frac{371.95}{58} =$ 6.41 quarts of sand (or screenings) required.

$\frac{132.5}{58} =$ 2.2 quarts of cement required.

In mixing my concrete I used 7 quarts of sand (or screenings) My reason for so doing was that in a Thesis made by W. A. Hawley and B. F. Krahl at the University of Illinois (Engineering News 43:374), these men found that stone filled with 125% of mortar was stronger than stone filled with either 100% or 75% of mortar. With these results in mind I wished to make sure that the voids in the stone were entirely filled.

I desired to make my concrete mediumly wet and so experimented with different quantities of water. I finally concluded that three quarts of water to every batch would give the proper consistency. This made one quart of water to every 216 cu. inches.

MIXING AND SUBSEQUENT OPERATIONS.

Before starting to mix concrete, I first got the molds ready, and as I mixed enough concrete to fill twelve cubes in a period, four cubes were made in the gang mold, and eight in separate molds. I thoroughly covered the sides and bottoms of the molds with oil so that the cubes might be more easily taken out and also to prevent the wood of the molds from absorbing moisture from the concrete. The mixing box being placed in a convenient location for all material, I measured out the required amount of sand (or screenings) and placed it in the bottom of the box. Then measured out the cement, placed it on top of the sand (or screenings) and turned the two over with a spade until they became a mixture of uniform color. Three molds were then set higher up in the mixing box and filled with stone after which the molds were lifted and the stone allowed to run down to the matrix. After turning the aggregate and matrix dry a few times I added water to the mass a little at a time from a pail. (It would probably have been better to spray the water, as otherwise it has a tendency to wash away the cement.) I then mixed the mass with both spade and hoe for five minutes and paid no attention to the number of turns, but continuously turned it during the alloted time. Then placed the concrete in molds in two or three inch layers and tamped until water freely flushed to the surface, after which I allowed it to set slightly before marking the cubes. I left the concrete to set in the molds from one and one half to two days, as I found that the corners fell off the cubes if taken out before. After taking them out of the molds, I transferred them to a small closet underneath the stairs leading to the main hall of the Institute. There was one steam pipe near the

floor of the closet, but the temperature was not uniform, being for a short time in the winter 40° to 50° F. and the remaining time between 65° and 70° F.

The cement Laboratory in which the concrete was mixed, averaged 70° F. in temperature and its general arrangement can be seen in Plate 2.

TESTING.

As the specified time intervals elapsed the cubes were brought into the laboratory to be tested on the Riehlé 200,000 lb. capacity machine. First the cubes were examined for the best two opposite faces. Upon these faces was then placed a coating of plaster of paris in order to make the bearing faces perfectly level and thus distribute the weight equally over both faces. The cube (taking one as the general case) was then placed upon some folded newspapers one inch thick and the the two then set on the lower compression block of the machine. An equal thickness of newspaper was placed on top of the cube, and platform "D" allowed to descend with what is known as a "medium slow" motion. The machine for its maintainence is operated by throwing in the gear "G" pushing lever 2 to the right and lever 3 to the left.

The majority of cubes showed cracks on the sides when they first began to give way and shortly afterward the beam would drop. When examined, most of the cubes were seen to have broken in a theoretical manner, by which I mean a break leaving a core in the form of two cones. Those which did not fulfil these conditions I have made a note of under "Results".

CONCRETE MADE WITH

SCREENINGS.				SAND.			
No.	Length of time stood.	Crushing strength in pounds.	Strength per square inch in lbs.	Crushing Strength in pounds.	Strength per square inch in lbs.	Length of time stood.	No.
			TABLE I.				
I	6 mo.	66,854	I, 857	57,400	I,59I	6 mo.	7
2	6 "	64,I62	I, 782	5I,205	I,422	"	8
3	"	62,340	I,73I	59,000	I,638	"	9
4	"	60,206	I,672	36,550	I,0I5	"	I0
5	"	60,432	I,678	30,320	842	"	II
6	"	58,300	I,6I9	29,I04	808	"	I2
			TABLE 2.				
I3	5 mo.	45,560	I,265	49,656	I,379	5 mo.	I9
I4	"	43,632	I,2I2	58,340	I,620	"	20
I5	"	46,924	I,303	53,6I5	I,489	"	2I
I6	"	40,I73	I,II6	48,492	I,347	"	22
17	"	49,55I	I,I36	48,74I	I,353	"	23
I8	"	4I,668	I,I57	2I,000	584	"	24
			TABLE 3.				
25	4 mo.	84,628	2,35I	44,828	I,245	4 mo.	3I
26	"	89,457	2,484	43,456	I,207	"	32
27	"	85,73I	2,38I	47,3I8	I,3I5	"	33
28	"	8I,4I5	2,26I	44,5I0	I,236	"	34
29	"	83,67I	2,324	47,423	I,378	"	35
30	"	83,302	2,3I3	45,379	I,260	"	36
			TABLE 4.				
37	3 mo.	98,330	I,342	38,I02	I,058	3 mo.	43
38	"	5I,050	I,4I8	46,520	I,292	"	44
39	"	45,820	I,272	44,405	I,233	"	45
40	"	52,690	I,463	24,984	694	"	46
4I	"	49,3I0	I,369	28,680	796	"	47
42	"	38,406	I,066	33,74I	938	"	48
			TABLE 5.				
49	I mo.	37,020	I,028	29,430	8I4	I mo.	55
50	"	35,I52	976	3I,0I2	86I	"	56
5I	"	36,870	I,024	30,I20	836	"	57
52	"	37,950	I,054	32,460	90I	"	58
53	"	33,I62	92I	3I,690	880	"	59
54	"	34,720	964	30,340	843	"	60

CONCRETE MADE WITH

	SCREENINGS.			SAND.			
No.	Length of time stood.	Crushing strength in pounds.	Strength per square inchin lbs.	Crushing strength in pounds.	Strength per square inch in lbs.	Length of time stood.	No
			TABLE 6.				
6I	2 weeks	24,600	683	32,600	908	2 weeks	67
62	"	27,I06	752	32,728	909	"	68
63	"	27,I90	758	3I,683	880	"	69
64	"	24,860	640	27,76I	77I	"	70
65	"	I9,856	550	25,334	703	"	7I
66	"	26,845	745	26,472	735	"	72
			TABLE 7.				
73	I week	37,390	I,033	35,330	98I	I week	79
74	"	37,585	I,052	38,67I	I,074	"	80
75	"	33,500	930	35,I66	976	"	8I
76	"	42,550	I,I82	36,255	I,007	"	82
77	"	38,306	I,064	40,07I	I,II3	"	83
78	"	38,420	I,067	44,62I	I,239	"	84

RESULTS.

Age 6 months, See Table I.

Av. crushing strength of concrete made with screenings-------------- 62,382 lbs.
" " " " " " " sand ------------------- 43,929 "
" strength per sq. inch " " " screenings-------------- I,732 "
" " " " " " " " sand -------------------- I,220 "

All but Numbers I0, II and I2 crushed in a theoretical manner. These were made at the same time and probably were not mixed thoroughly enough, as the sides of some of the stones were clean. By clean I mean not entirely covered with mortar.

Age 5 months, See Table 2.

Av crushing strength of concrete made with screenings -------------- 44,584 lbs.
" " " " " " " sand -------------------5I,768 "
" strength per square inch" " " screenings -------------- I,233 "
" " " " " " " " sand ------------------ I,438 "

Crushing strength of Cube No.24 was not averaged in the result as it crushed at so many less pounds weight than the rest of the cubes. All the cubes but No. 24 broke in a theoretical manner.

Age 4 months, See Table 3.

Av. crushing strength of concrete made with screenings ------------84,697 lbs.
" " " " " " " sand -----------------45,485 "
" strength per sq. in. " " " screenings ------------- 2,352 "
" " " " " " " " SAND------------------ I,263 "

Cube No. 26 broke on one side only, which was probably caused by uneven pressure being exerted while in the testing machine. Cube No. 3I broke squarely down the middle, but all the rest broke in a theoretical manner.

Age 3 months, See Table 4.

Av. crushing strength of concrete made with screenings ------------47,60I lbs.
" " " " " " " SAND ------------------43,009 "
" strength per sq. in. " " " screenings ------------ I,322 "
" " " " " " " " sand ----------------- I,I94 "

Results obtained be crushing cubes No. 46, 47 and 48 are not averaged in the final result for they were probably made too wet, as loose stones could be picked from the concrete. When concrete is made too wet, the water has a tendency to wash the cement away from the stones.

Age one month, See Table 5.

Av. crushing strength of concrete made with screenings ------------35,8I2 lbs.
" " " " " " " sand ----------------30,843 "
" strength per sq. in. of " " " screenings ------------ 994 "
" " " " " " " " " sand ------------------ 856 "

All broke theoretically.

Age two weeks, See Table 6.

Av. crushing strength of concrete made with screenings ------------26,I20 lbs.
" " " " " " " sand ---------------29,430 "
" strength per sq in. " " " screenings ------------ 725 "
" " " " " " " " sand ----------------- 8I7 "

This concrete all seemed to be a very poor quality and practically all of the cubes, after showing a few cracks, crushed entirely down. Strength of cube No. 65 not averaged in final result.

Age one week, See Table 7.

Av. crushing strength of concrete made with screenings-----------37,957 lbs.
" " " " " " " sand ---------------38,352 "
" strength per sq. in. " " " screenings ---------- I,054 "
" " " " " " " " sand ---------------- I,065 "

The concrete contained in the cubes used for the weeks test seemed to be of uniform texture and all the cubes broke theoretically.

See below.

I	6 mo.	5 mo.	4 mo.	3 mo.	I mo.	2 wks.	I week.
2	I,732	I,238	2,352	I,322	994	725	I,054
3	I,220	I,438	I,262	I,I94	856	8I7	I,065
4	Sc.	S.	Sc.	Sc.	Sc.	S.	S.

I-----Length of time allowed cubes to stand.

2---Strength in lbs. per sq. inch of screenings concrete.

3----- " " " " " " " sand "

4-----Kind of concrete showingbest test for indicated lengths of time.

Sc. designates screenings concrete.

S. " sand "

Average strength in lbs. per sq. inch of all tests.

Concrete made with screenings $\frac{9,4I7}{6} =$ I,569

" " " sand $\frac{7850}{6} =$ I,308

In all cases when solving for the strength in lbs. per sq. inch of concrete, I divided the result found for the crushing strength of concrete cubes by 36. The cubes being 6 inches on a side, each surface therefore equal 36 square inches. I made six cubes for each test in order to get a fair average result. In finding the various

Curves showing relative strength per square inch of Concretes made with Limestone screenings and torpedo sand.

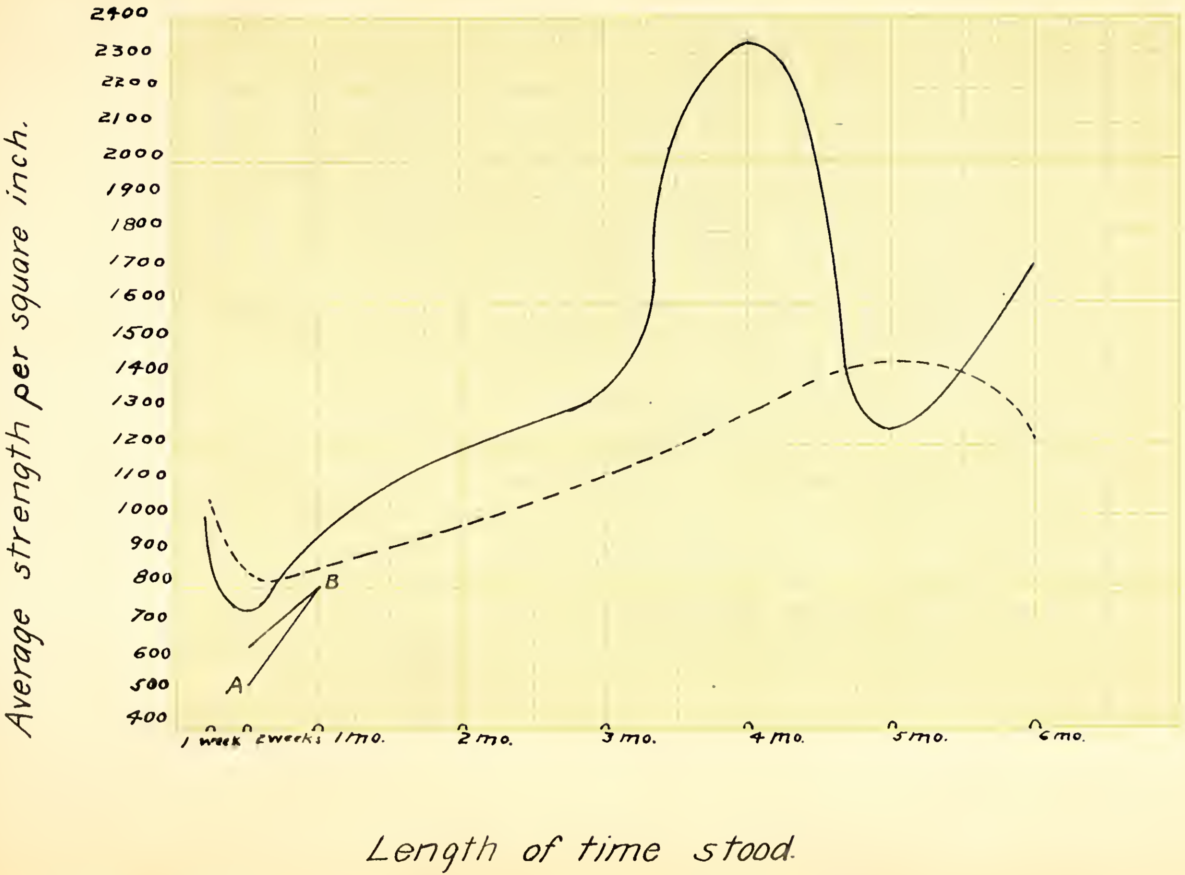
———————————— Curve of screenings concrete.

— — — — — — — — — — — — Curve of sand concrete.

A. — B. Curve shows increase in tensile strength per square inch of (neat) cement used.

A. - Tensile strength at end of 7 days.

B. - Tensile strength at end of 28 days.


Average strength per square inch.
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
1 week
2 weeks
1 mo.
2 mo.
3 mo.
4 mo.
5 mo.
6 mo.
A
B
Length of time stood.

averages, I added the results together and divided by 6, except in those cases noted.

The results are not altogether uniform, which probably is due to my inexperience in mixing concrete, although I tried to mix all the separate quantities in the same way. Results would probably have been higher if the cubes were kept under water, but as they were all under the same conditions, the results I suppose, are relatively the same.

C O N C L U S I O N S .

From the results found inthis series of tests, concrete made with limestone screenings seems to be superior to concrete made with torpedo sand. However only in this case under the conditions stated before are these results true, for some one else testing concretes made with screenings and with sand, might arrive at wholly different conclusions. The tendency to generalize conclusions from specific tests, I have often seen commented on, and I wish to keep from such an error.

Adhering to the above statements, the conclusions I have drawn from the results of my test are as follows:

(I) Concrete made with limestone screenings has greater strength than concrete made with torpedo sand. (in general)

(2) For short periods of time (up to one month) concrete made with torpedo sand has greater strength than concrete made with limestone screenings.

(3) More uniform strength is developed by concrete made with torpedo sand than by concrete made with limestone screenings.

(4) Concrete made with limestone screenings increases in strength with age, to a greater degree than concrete made with torpedo sand.

The reason that concrete made with limestone screenings shows a higher compressive strength than concrete made with torpedo sand, in my opinion is due to a natural cementatory property in the screenings. I had several opportunities to notice this quality while employed as mentioned in the Introduction. After being wet, screenings packed into a smaller space than they occupied when dry, were much harder to handle with a shovel. Another explanation is that water packs the particles more closely together. When mixed with cement such a matrix probably fills the voids of the aggregate better and makes a more uniform concrete than a matrix made of sand and cement.

REMARKS.

Structures made with concrete using sand and cement as a matrix are so well known that I wish to mention a few structures on which stone-dust or screenings were used; and to give the opinions of some engineers regarding the use of such material.

(Reference) Engineering News, Volume 50, page 454.

Screenings or as they are called in England, stone-dust, were used in concrete for the five large dams of the Birmingham, England, water supply, and also in the great Vrymay Dam for the Liverpool, England,water works. In our own country they were used for making concrete on the coast defense fortifications at Boston, Mass. They were

also used in making the Jerome Park Reservoir, New York City, and because the reservoir was defective in some ways, they were said to have been the cause thereof. The report submitted stated that screenings and cement did not make a good matrix for concrete. A commission of eminent engineers disproved any such theory by giving their personal experiences with the use of screenings, and by a series of exhaustive tests.

In the Engineering News VOL. 48, page I82 is an article by T. W.Symonds on "Concrete Break Water Construction at Buffalo, N. Y." He recommends the use of Crusher Run limestone (i. e. limestone that is the entire product of the crusher), as he says that the best results were obtained in that way on the above work, as the unscreened part is the most valuable portion of broken stone in his opinion.

Capt. H. Taylor, Eng. Corps. U. S. N., has an article "Notes on Cement and Concrete Construction in the U. S. Gov't. Fortifications Works for I902," in the Engineering News Vol. 49, Page 306. In the report the relative strength of cement mixed with sand and mixed with screenings is taken up. I600 briquettes were tested, the length of tests being 24 hours, 7 days, I month, 3 months, 6 months, and I year. Briquettes made of cement and screenings all showed greater strength than briquettes made of cement and sand, with the exception of the 24 hour test.

"Comparative Tests of Concretes Made With Limestone Screenings, Pit Sand and Gravel" is the title of an article by G. W. Griesenauer, Cement expert and tester for the Chicago, Milwaukee and St Paul Railway. It may be found in Engineering News Vol. 49, page 342.

The tests extend over two years and almost without exception show the superiority of limestone screenings over either sand or gravel. "These tests" the article states, "are suggestive in view of the thousands of car loads of limestone screenings that are separated from the crushed stone at the crusher mills, and piled up as rejected waste, supposed to be valueless material." The theories advanced by Mr. Griesnauer as to the causes of limestone screenings being superior to sand or crushed gravel are: (I) The limestone is porous as compared to sand or gravel, therefore there is the possibility of its becoming saturated with the fluid mixture of cement and water. The smaller the particles of stone the more completely saturated will they become. This suggests a tendency of the mixture to become homogeneous in composition and simultaneously homogeneous in strength to a greater degree than is possible for a sand or other less porous material similarly mixed. (2) The elements contained in limestone are solid forming or crystallizing elements. When these elements are attacked by the active crystallizing and solid forming elements of the cement, they form a chemical union with the cement. The more complete the saturation the more complete will be the union; thus the limestone and cement form an intermingled homogeneous mass. (3) A mixture of cement and limestone screenings packs very closely, the particles being such as to fit themselves closely to one another, thus reducing the voids.